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IS CO<sub>2</sub> ICE PERMANENT? Bernhard Lee Lindner, Atmospheric and Environmental Research, Inc., 840 Memorial Drive, Cambridge MA 02139, USA.

Carbon dioxide ice has been inferred to exist at the south pole in summertime [1,2], but Earth-based measurements in 1969 of water vapor in the martian atmosphere suggest that all CO<sub>2</sub> ice sublimed from the southern polar cap and exposed underlying water ice [3]. This implies that the observed summertime CO<sub>2</sub> ice is of recent origin.

However, Fig. 1 shows that theoretical models of the energy budget of the surface that simulate the formation and dissipation of CO<sub>2</sub> ice have been unable to preserve seasonal CO<sub>2</sub> ice at the south pole and still obtain agreement with observations of the polar cap regression and the annual cycle

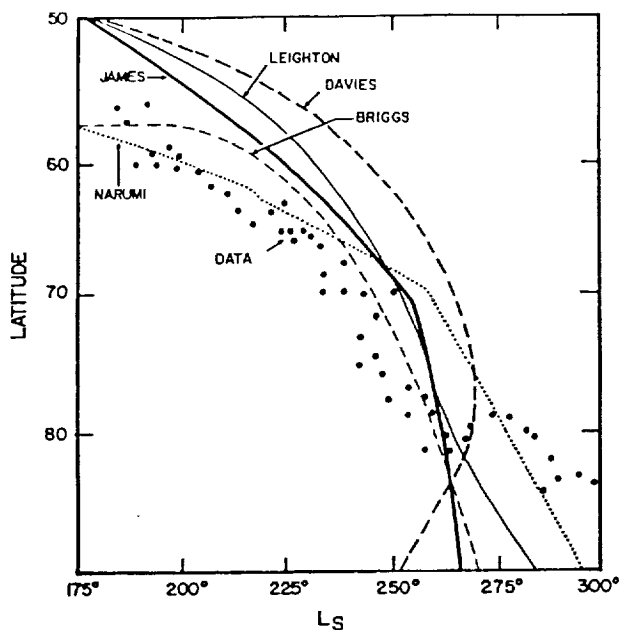


Fig. 1. The seasonal recession of the south polar cap as observed over the last 20 years [22] and as predicted by models [4,6-9]. (The aerocentric longitude of the Sun,  $L_s$ , is the seasonal index;  $L_s = 0^\circ, 90^\circ, 180^\circ$ , and  $270^\circ$  correspond to northern spring equinox, summer solstice, autumnal equinox, and winter solstice respectively.)

in atmospheric pressure [4-10]. This implies that either these models improperly treat the energy budget or that CO<sub>2</sub> ice from an earlier time is exposed in summer.

An exact comparison to data is difficult, considering that the edge of the polar cap is usually patchy and ill defined [18,19], in large part due to terrain that is not included in any polar cap model. The edge of the polar cap is also diurnally variable since ice frequently forms at night and sublimates during the day. There is also some year-to-year variability in polar cap regression [20,21].

Several processes have been examined that might retain the good agreement to observations of the annual cycle in atmospheric pressure and to overall polar cap regression, and yet allow for better agreement at the south pole, without requiring old CO<sub>2</sub> ice. The radiative effects of ozone were suggested as important [11], but were shown numerically to be unimportant [12,13]. However, the radiative effects of clouds and dust [12] and the dependence of frost albedo on solar zenith angle [14,15] do allow for better agreement at the pole while maintaining good agreement to overall polar cap regression and the atmospheric pressure cycle [16]. Penetration of sunlight through the seasonal ice also has a marginal positive effect on CO<sub>2</sub> ice stability at the pole itself because it allows some solar radiation that would otherwise sublime overlying CO<sub>2</sub> seasonal ice to sublime ice within the residual polar cap [17].

Figures 2 and 3 show my model predictions for polar cap regression compared to observations. Before solar longitude of  $250^\circ$ , south polar cap regression is predicted to be similar to that predicted by earlier models (compare to Fig. 1). However, the new model retains CO<sub>2</sub> ice year round at the

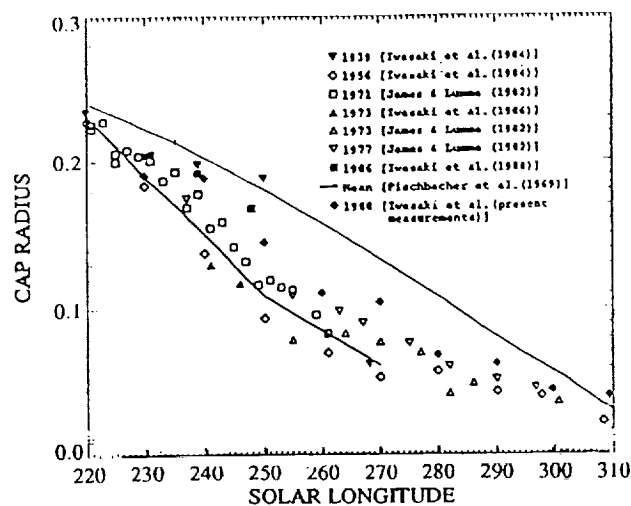


Fig. 2. The regression of the south polar cap, as observed for various years (taken from [23]) and as simulated by my model (thin line), as a function of the aerocentric longitude of the Sun ( $L_s$ ). The cap radius is that which would be measured on a polar stereographic projection of the south polar region; the units of the radius are fractions of the planetary radius of Mars.

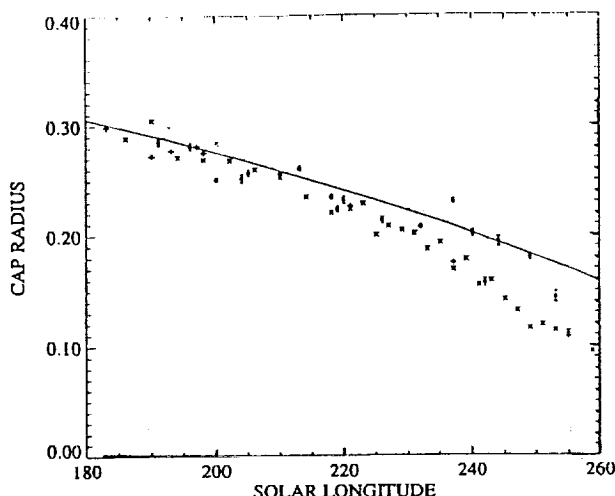


Fig. 3. The regression of the south polar cap, as observed in 1986 (solid circles), 1971 (crosses), and 1977 (plus signs) (taken from [21]) and as simulated by my model (thin line), as a function of the aerocentric longitude of the Sun ( $L_s$ ). Two-sigma error bars are indicated for the 1986 data; the errors are smaller for the denser 1971 data and for the 1977 Viking data.

south pole. Unfortunately, the model does overpredict polar cap extent in early southern summer (see Fig. 2).

In summary, it appears possible to construct an energy balance model that maintains seasonal  $\text{CO}_2$  ice at the south pole year round and still reasonably simulates the polar cap regression and atmospheric pressure data. This implies that the  $\text{CO}_2$  ice observed in the summertime south polar cap could be seasonal in origin, and that minor changes in climate could cause  $\text{CO}_2$  ice to completely vanish, as would appear to have happened in 1969 [3]. However, further research remains before it is certain whether the  $\text{CO}_2$  ice observed in the summertime south polar cap is seasonal or is part of a permanent reservoir.

**Acknowledgments.** I acknowledge support by NASA contracts NASW 4444 and NASW 4614, under the Planetary Atmospheres Program and the Mars Data Analysis Program.

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**THE INTERANNUAL VARIABILITY OF POLAR CAP RECESSIONS AS A MEASURE OF MARTIAN CLIMATE AND WEATHER: USING EARTH-BASED DATA TO AUGMENT THE TIME LINE FOR THE MARS OBSERVER MAPPING MISSION.** L. J. Martin<sup>1</sup> and P. B. James<sup>2</sup>, <sup>1</sup>Lowell Observatory, 1400 West Mars Hill Road, Flagstaff AZ 86001, USA, <sup>2</sup>Department of Physics and Astronomy, University of Toledo, Toledo OH 43606, USA.

**Seasonal Cycles of Dust, Water, and  $\text{CO}_2$ :** The recessions of the polar ice caps are the most visible and most studied indication of seasonal change on Mars. Strong, if circumstantial, evidence links these recessions to the seasonal cycles of  $\text{CO}_2$ , water, and dust. These phenomena and their interactions will be the subject of an MSATT workshop next year titled "Atmospheric Transport on Mars." Briggs and Leovy [1] have shown from Mariner 9 observations that the atmospheric polar hoods of the fall and winter seasons are at least partially water ice clouds. Around the time of the vernal equinox, this water ice may precipitate onto the surface that includes  $\text{CO}_2$  frosts. The sublimation of the outer edge of the seasonal cap begins about this same time, and we begin to observe its recession. During the recession of the north cap we also observe circumpolar clouds that are believed to be formed by water vapor from the subliming cap [2]. Some observations suggest that at least part of the sublimed water and/or  $\text{CO}_2$  reforms as surface ice toward the cap's interior. This "new" ice is probably the bright component of the polar caps that is seen on Earth-based observations. This would explain the south cap's appearance as that of a shrinking donut during its recession [3]. Near the edge of the shrinking cap, dust activity is also evident on the Viking images [4]. This may result from off-cap winds generated from sublimation and/or dust that might be released from within or beneath the ices. It has been found that all of Mars' major dust storms that have been observed to date occurred during the broad seasons when either the north or south polar cap was receding [5]. There are short seasonal periods around the beginning and ending of cap recessions when no major dust